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A pre-study of background color effects on the working memory area of the brain

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Abstract

Many studies have suggested that the design of the tablet screen could give an effect to the tablet users' performance. The purpose of this study is to investigate the effects of screen background colors on the brain functions for elderly and young people when they are performing a task on a tablet computer. Twenty university students and 10 elderly people were recruited for participating in the experiment. The subjects were told to count the number of circles on a five different background colors, which are white, blue, yellow, red, and green randomly. This step was done in a short period of time. The average percentages of correct answers for the circle counting tasks that the subjects performed were higher with all background colors for both young and elderly people compared to the white background color. The results indicate that white color may not be the best choice for a background color of a tablet screen for best performance and attention for both young and elderly people.

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Keywords: background color; working memory; tablet computer; NIRS

1. Introduction

The use of a tablet computer at a high speed internet access that has spread in our life, is a necessary part for people. Its flexibility, effectiveness, and its promptness have been contemplated as an ideal tool for either elderly or

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young people[1]. Tablet computers have been used to enhance people's daily lives and to intensify the cognitive ability of the brain[2]. Many studies have proposed that when people using tablet computer, the design of a tablet computer screen can possibly give an effect to attention, concentration, and performance of the brain[3]. A number of studies also have examined font type and background color combinations on a computer screen in relation to the impact on task performance[4, 5].

Hall and Hanna indicated that greater contrast ratios between background and font colors can lead to effective readability[6]. Mehta and Zhu study of background colors has shown that the task performance is likely to be affected by the background colors[7]. Yamazaki examined whether the background colors of computer-based and Web-based tests influenced the scores of test takers and suggested that neurological factors associated with color characteristics can affect the test score averages of university students for different background colors[8]. A preliminary study also by Yamazaki and Eto on the effects of blue backgrounds on a tablet screen for elderly people suggested that white color may not be the best choice for a background color of a tablet computer screen for elderly people. The brain activity of each subject was recorded and observed by using near-infrared spectroscopy (NIRS) system in the study by Yamazaki and Eto. In this study, the authors investigated the effect of different background colors in terms of performance and brain functions of elderly and young people when they perform a task on a tablet computer. Therefore, in this study, we also compared the brain activity of young and elderly people to see a difference in their working memory area and concentration ability. We expect that the results of this study could give a help to provide a suitable training method to control the rate of mental declining.

2. Experiment

The authors conducted an experiment to investigate the concentration levels, attention and working memory of elderly and young people when they performed task on a tablet computer with five different screen background colors: white, blue, yellow, red, and green. In order to identify which part of subjects' brain is activated, a circle counting task was used in this experiment. We recorded and observed the brain activities of the subjects by using a NIRS system during the task.

2.1. Circle counting task

Five sets of the circle counting task with each background color and black text were developed for this experiment. Each test set consisted of ten circle counting task questions. All task pages were designed in the same way: three different symbols including circle were drawn randomly and presented in black on a single-color background of the tablet screen. The subjects were told to count the number of the circle on each background color in a short period of time. The characteristics of five background colors used in this experiment are listed in Table 1. The table summarizes their hexadecimal color codes, brightness and color differences between the background colors and black foreground color. Formulas suggested by the World Wide Web Consortium (W3C) were used to calculate these values[9]. Figure 1 shows the examples of the circle counting task pages of black symbols on white, blue, yellow, red, and green background colors. Lenovo YOGA 2 tablet computer, which has a screen size 10.1" (1920 by 1200 pixels), was used in the experiment.

Table 1. Hexadecimal codes, brightness differences, color differences, luminance ratios, and luminance difference of five background colors with black symbols.

Background color	Hexadecimal color code	Brightness difference	Color difference	Luminance ratio	Luminance difference
White	#FFFFFF	255	765	21	1
Blue	#0000FF	29	255	2.44	0.0722
Yellow	#FFFF00	225.93	510	19.56	0.9278
Red	#FF0000	76.245	255	5.25	0.2126
Green	#008000	75.136	128	4.09	0.1544

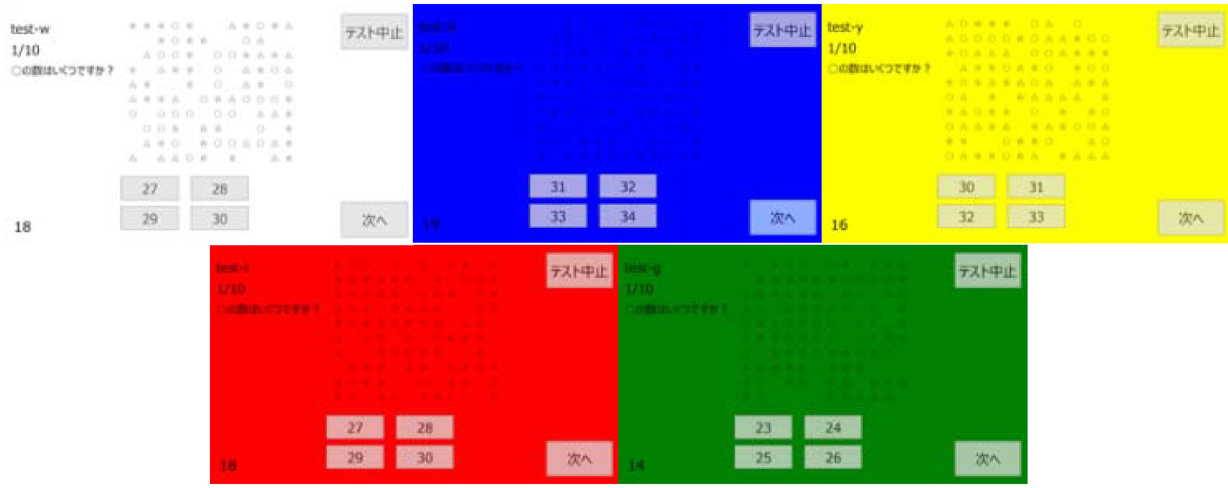


Fig. 1. Example of circle counting task pages for each background color.

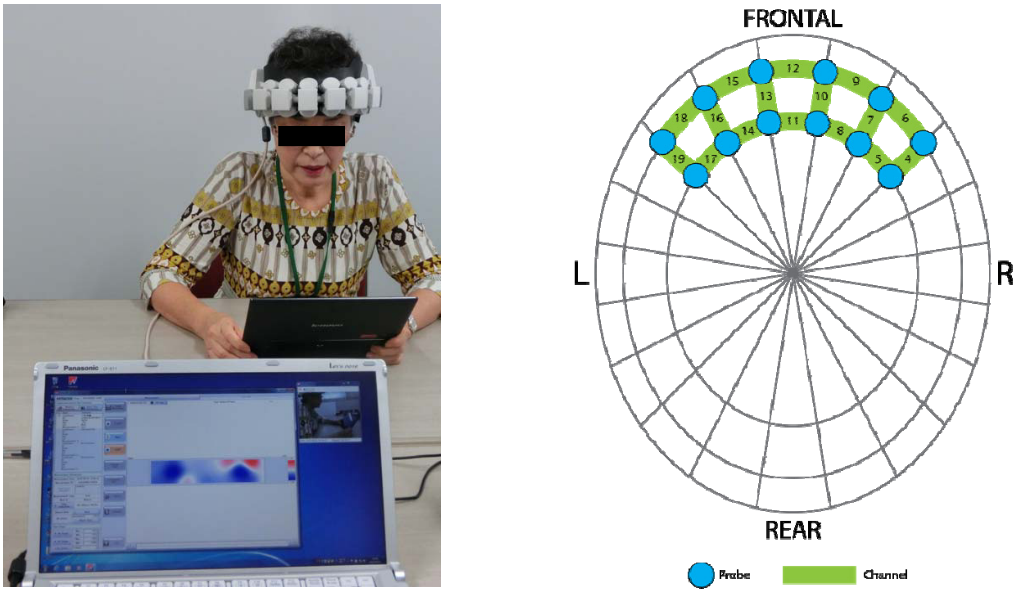
2.2. Subjects

Twenty Japanese subjects in their twenties (15 males, 5 females) and 10 healthy elderly people who were over 65 years old (7 males, 3 females) were recruited to participate in this study. None of them was reported to have a color vision deficiency at the time of the experiment. The subjects were given explanations before undertaking the tasks. All of them performed the task on the tablet computer without any trouble during the experiment.

2.3. Instrumentation and method

All the subjects performed the task with black symbols on different five background colours randomly. Each background colour consisted of ten circle counting task questions. The duration was set to 30 seconds for one circle counting page. The subjects chose the answer by speaking out loud the answer and pushing the button on the screen from four choices for the answers. All the subjects finished the task and gave the answer in the time given. The scores that obtained from the circle counting task were analysed in order to see a difference between the five background colours of the test sets.

After finishing the circle counting task for each colour, the subjects were answered a questionnaire that designed to obtain their feelings about the circle counting task experiment. By using a five-point scale, the questionnaire asked about the tiredness, readability, difficulty, and the concentration levels during taking the test. The relative changes in haemoglobin concentrations in subjects' brain were measured and recorded by using the Hitachi NIRS (WOT-100) with 16 channels while the subjects performed the task. The NIRS machine was applied to subjects' forehead as shown in Figure 2 (a). Figure 2 (b) shows the positions of NIRS probes that covered the frontal regions of subjects' brain. The relative changes in oxy-haemoglobin, deoxy-haemoglobin, and total haemoglobin concentrations were recorded for each subject.



(a) (b)

Fig. 2. (a) An elderly female subject wearing wearable NIRS while performing the task; (b) Mapping of channel and probe numbers of the wearable NIRS.

3. Results

The average percentages of circle counting tasks answered correctly by the subjects for each background color and the variance were calculated and summarized in Table 2.

Table 2. Average percentages of the circle counting task score of young subject and elderly subject.

Background color	Average % of circle counting task score		Variance	
	Young	Elderly	Young	Elderly
White	7.15	6.1	2.9763	6.5444
Blue	8.15	7.2	2.0289	8.1778
Yellow	8.4	7.8	1.9368	3.9556
Red	7.6	6.9	3.6211	3.2111
Green	7.9	7.3	2.8316	5.3444

The average percentages for circle counting tasks performed by both young and elderly subjects were the lowest for the white background color compared to other background colors. The authors also conducted a t-test (α=0.05) to examine the significance of differences between each background color with the white background color for the correct answers of the circle counting task for both young and elderly people. Table3 summarizes t-test results for both young and elderly people for background colors that had a significance difference with white background color.

Table 3. Examination results of t-tests for the circle counting task score: (a) Young subjects; (b) Elderly subjects.

(a) Young subjects

Background color	Variance	Pearson correlation	t stat	P(T<=t)
Blue	2.0289	0.483	-2.7568	0.0125
Yellow	1.9368	0.3683	-3.1523	0.0052*
Red	3.6211	0.7567	-1.5768	0.1313
Green	2.8316	0.6219	-2.2627	0.0356

* p < 0.01

(b) Elderly subjects

Background color	Variance	Pearson correlation	t stat	P(T<=t)
Blue	8.1778	0.8019	-2.012	0.0751
Yellow	3.9556	0.463	-2.2344	0.0523
Red	3.2111	0.8265	-1.7143	0.1206
Green	5.3444	0.5956	-1.7241	0.1188

As Table 3 shows, we considered that yellow, blue, and green background colors have significant differences with white background colors for young people, while there are no significant differences with the white background color for the elderly people in circle counting task scores. The t-test results showed a significant difference at $p < 0.01$ level between white and yellow background colors. The authors then observed the significant differences for the hemoglobin (Hb) concentration changes that were recorded by the wearable NIRS. The analysis results demonstrated that several channels had a significant difference between the white background color and other colors for both young and elderly people. The results are shown in Table 4.

Table 4. Examination results of t-tests for the Hb concentration changes: (a) Young subjects; (b) Elderly subjects.

(a) Young subjects

Channel	Background color	Variance	Pearson correlation	t stat	P(T<=t)
6	Blue	7.3591	0.7444	2.2388	0.0373
16	Blue	0.2141	0.2256	2.1924	0.041
16	Green	1.3919	0.8344	2.4284	0.0253
16	Red	0.3317	0.6208	2.1173	0.0477

(b) Elderly subjects

Channel	Background color	Variance	Pearson correlation	t stat	P(T<=t)
6	Blue	0.0555	0.509	2.7998	0.0207
6	Red	0.0916	0.6168	3.1796	0.0112
9	Yellow	0.3214	0.8262	2.3028	0.0468
12	Yellow	0.5455	0.7586	2.568	0.0303

As shown in Table 4, CH6 showed a significant difference in Hb concentration changes for blue background color only in the case of young people, while CH16 showed a significant difference in Hb concentration changes for blue, red, and green background colors. On the other hand, for elderly people, CH9 and CH12 showed a significant difference in Hb concentration changes for yellow background colors, while CH6 showed a significant difference in

Hb concentration changes for blue and red background colors among all 16 channels. However, the NIRS concentration values for these channels were higher for the white background color.

Table 5. Questionnaire results answered by subjects: (a) Young subjects; (b)Elderly subjects.

(a) Young subjects

Background color	Tiredness	Readability	Concentration	Difficulty
White	2.8	2.9	3.7	3.0
Blue	3.2	2.7	3.6	3.0
Yellow	3.0	3.8	3.5	2.5
Red	3.8	2.5	3.3	3.1
Green	2.8	2.8	3.2	3.2

(b) Elderly subjects

Background color	Tiredness	Readability	Concentration	Difficulty
White	3.7	3.6	3.8	2.3
Blue	3.7	2.9	3.4	2.6
Yellow	3.5	3.0	3.9	2.4
Red	3.6	3.0	3.5	2.6
Green	3.5	2.8	3.9	2.7

Table 5 indicated the questionnaire results answered by subjects after performing the circle counting task. The questionnaire was conducted by using a five-point scale from 1=least to 5=most for each item asked. The questionnaire results indicated that young subjects had concentrated the most on the white background color and had felt least tired while they were counting black circles on the white and green background colors. They also answered that the figures were easiest to read and the task seemed least difficult on the yellow background color. On the other hand, the elderly subjects preferred yellow and green background colors for the background color, and they concentrated the most and had felt least tired. Moreover, the white background color made the figures easiest to read and the task seemed least difficulty for elderly subjects.

4. Discussion & Conclusion

In this study, the brain activities of elderly and young subjects were analyzed in order to investigate the effects of background colors of a tablet screen. The circle counting task scores were higher for all other background colors than those of the white background color for both young and elderly subjects. On the other hand, NIRS measurement results showed that some areas on the frontal cortex of the brain were highly activated when the subjects performed the circle counting task with a white background color compared to other background colors for both young and elderly subjects, even though the average of circle counting task scores for white background color the lowest. We suspect that subjects performed the task with more stress on the brain for the white background color. However, in the future we need to analyze in detail to find which brain regions corresponded to the activated channels.

Moreover, in this study no strong relationship was found between the performance scores and the concentration level or the degree of fatigue of the subjects[3, 8]. These results suggest that the white background color with black symbols may not be the best choice for tablet screens both for elderly or young people. In Yamazaki studies, Hb concentration changes showed that the brain areas related to eye movements tended to be more active when subjects were performing tasks on a white background color[3, 8]. However, in the future we need to interpret the channels that corresponded to brain regions. Then, the working memory area of young and elderly people also should be focused as working memory is responsible for processing new and ready stored information and working memory declines with advancing age[12]. The reading span task also will be conducted in the next step in order to investigate the working memory area of the brain for young and elderly people. The authors also would like to compare the brain activities of young and elderly people. Therefore, the number of subjects also need to be increased, since brain functions are known to vary among individuals.

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